

conducting electrical energy from the core third material **140C** to the adjacent second material **140B**. Likewise, the medial (second) conductive material **140B** is in contact with the outer (first) conductive material **140A**.

FIG. 5 further illustrates that shows that the proximal end **126a** and distal end **126b** of the engagement surface **125**, as well as the medial conductive material **140B**, are spaced apart from the core (third) conductive material **140C** by an insulator material **152** (see also FIG. 3). Thus, the member **120** can only conduct electrical energy to the engaged tissue via conductive layers **140C**, **140B** and through the engagement surface **125**. The body portions **154** of the member **120** thus cannot conduct electrical energy to tissue and preferably are a portion of an insulative body to prevent substantial thermal conduction therethrough.

Of particular interest, still referring to FIG. 5, the medial (second) conductive material indicated at **140B** comprises a polymeric material or matrix having a resistance (i.e., impedance to electrical conduction therethrough) that changes in response to its temperature. Such materials are typically known in the art as polymer-based temperature coefficient materials, and sometimes specifically described as thermally sensitive resistors or thermistors whose characteristics exhibit very large changes in resistance with a small change of body temperature. This change of resistance with a change in temperature can result in a positive coefficient of resistance where the resistance increases with an increase in temperature (PTC or positive temperature coefficient material). The scope of the invention also includes medial conductive material **140B** (see FIG. 5) of a negative temperature coefficient (NTC) material wherein its resistance decreases with an increase in temperature.

In one type of PTC material, a ceramic PTC layer can be engineered to exhibit unique resistance vs. temperature characteristics that can maintain a very low base resistance over a wide temperature range, with a dramatically increasing resistance (i.e., several orders of magnitude) above a specific temperature of the material which is sometimes referred to as a Curie point or *switching range* as illustrated in FIG. 6. As will be described below, one purpose of the invention is to fabricate the medial conductive material **140B** (see FIG. 5) to have a selected *switching range* between a first temperature (**Temp₁**) and a second temperature (**Temp₂**) that approximates the targeted tissue temperature in the contemplated thermally-mediated therapy. The selected switching range, for example, can be any substantially narrow

2°-5° C. range within the broader hyperthermia field (e.g., 45°-65° C.) or the ablation field (e.g., 65°-200° C.). It can be understood that the engagement plane **125** will cause the application of active Rf energy to tissue in contact therewith, and proximate thereto, until the medial conductive layer **140B** is heated to the selected switching range. Thereafter, the mass of the working end **122** is elevated to a temperature at or above the selected switching range and will thereafter

5 conduct or radiate thermal effects to the engaged tissue.

Thus, the critical increase in temperature of medial second conductive material **140B** is typically caused by the transient high temperature of tissue that is caused by active Rf heating of the tissue. In turn, heat is conducted back through the layer of the first conductive material **140A** to medial conductive material **140B**. (Another embodiment below describes the use of direct electrical current flow to thus cause internal heating of the medial conductive material **140B**, see FIG. 24). A Suitable PTC material can be fabricated from high purity semi-conducting ceramics, for example, based on complex titanate chemical compositions (e.g., BaTiO₃, SrTiO₃, etc.). The specific resistance-temperature characteristics of the material can be designed by the addition of dopants and/or unique materials processing, such as high pressure forming techniques and precision sintering. Suitable PTC materials are manufactured by a number of sources, and can be obtained, for example from Western Electronic Components Corp., 1250-A Avenida Acaso, Camarillo, CA 93012. Another manner of fabricating the medial conductive material **140B** is to use a commercially available epoxy that is doped with a type of carbon. In fabricating a substantially thin medial conductive layer **140C** in this manner, it is preferable to use a carbon type that has single molecular bonds. It is less preferred to use a carbon type with double bonds.

As can be seen in FIG. 5, the third conductive material or electrode **140C** at the core of member **120** is

20 operatively connected to the Rf source **150A** by a first electrical lead **156** that defines a first polarity of the Rf source. In this preferred embodiment, the conductive engagement surface **140A** is coupled to a second electrical lead **158** that defines a second or opposing polarity of the Rf source **150A**. A ground pad indicated at **160** in FIGS. 4 and 5 also is coupled to the first lead **156** to accomplish a preferred method of the invention, as will be described below.

2. Method of use of Type "A" embodiment. Referring to FIGS. 7A-7B, the manner of utilizing the probe 100 of FIG. 1 to perform a method of the invention is illustrated. FIG. 7A illustrates a tumor tissue **tt** targeted for hyperthermic treatment or ablation. For example, the targeted tissue **tt** can be a tumor in a patient's liver wherein the thermally-mediated therapy is defined by the delivery of a thermal energy dose that comprises (i) a minimum selected temperature across the targeted tissue **tt**, and (ii) the maintenance of the selected temperature of a selected time interval. As an example, consider that the parameters of a therapy is to deliver a minimum of 70° C. for 600 seconds to the targeted tissue including margins **m**, although the temperature and duration for a particular therapy can be any suitable parameters ranging from about 40° C. to 200° C. for from about 10 seconds to 20 minutes.

In the exemplary procedure, the physician selects a working end that carries a medial conductor matrix 140C (see FIGS. 5 and 6) that has a switching range at or about 70° C., or more particularly a conductor matrix 140C that increases in resistance by a factor of 100 or more from its low base resistivity (see FIG. 6) as its temperature moves in a narrow switching range from about 68° C. to 72° C.

As can be understood from FIG. 7A, any overlying tissue such as an abdominal wall can be penetrated by any suitable means such as a trocar that leaves a cannula (not shown) in place. Ultimately, the working end 122 of the energy delivery member or body 120 is placed in a desired relationship to the targeted tissue **tt** in a predetermined location, for example through the center of the targeted tissue **tt** as depicted in FIG. 7A. The cross-section of the energy delivery member 122 can be equivalent to a needle, with any size in the range of about 30 to 12 gauge. A suitable imaging system is first used to define the volume of the targeted tissue **tt** and thereafter to localize the engagement surface 125 relative to the tumor. The length dimension **L** of the engagement surface 125 is selected to provide a suitable pattern for volumetric ablation of the targeted tumor tissue **tt**. The types of suitable imaging systems include, but are not limited to, ultrasound imaging, computerized tomography (CT) scanning, x-ray fluoroscopy, magnetic resonance imaging (MRI), and the like. The methods of using such systems to define the targeted tissue volume and localization of the engagement surface 125 are well known to those skilled in the art. For use in some imaging systems, the proximal, distal or other perimeters of the engagement surface 125 can carry imaging-sensitive markings (not shown).